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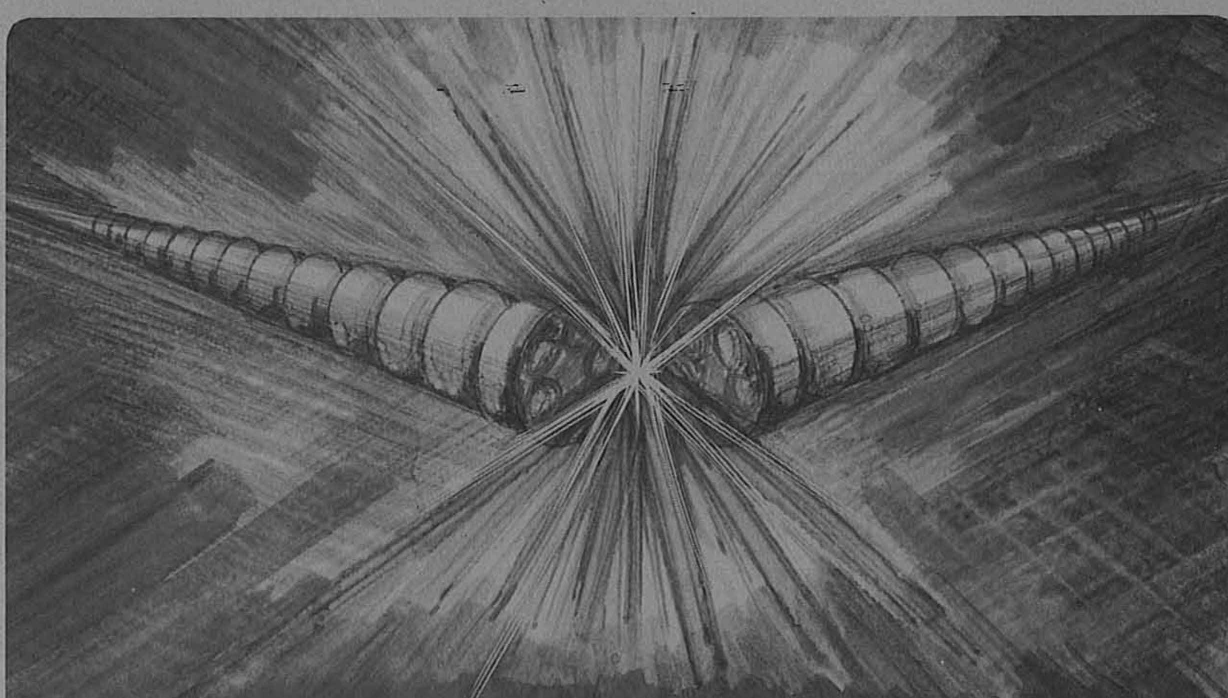

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PEP-II Design Update and R&D Results

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ABSTRACT

We describe the present status of the PEP-II asymmetric *B* factory design undertaken by SLAC, LBL, and LLNL. Design optimization during the past year and changes from the original CDR design are described. R&D activities have focused primarily on the key technology areas of vacuum, RF, and feedback system design. Recent progress in these areas is described. The R&D results have verified our design assumptions and provide further confidence in the design of PEP-II.

1. INTRODUCTION

The conceptual design for the PEP-II asymmetric *B* factory, carried out as a collaboration of SLAC, LBL, and LLNL, was completed in February, 1991 [1]. The design goal for PEP-II, which comprises a high-energy ring (HER) containing 9 GeV e^- and a low-energy ring (LER) containing 3.1 GeV e^+, is to provide a luminosity of $\mathcal{L} = 3 \times 10^{33}$ cm^{-2} s^{-1}. Since the conceptual design report (CDR) was completed, the design has continued to evolve. Significant changes have occurred in the areas of the interaction region (IR) design, the LER lattice, and the injection scheme. In addition to the design activities, R&D is being carried out in the technological areas of vacuum, RF, and feedback. The main design changes and recent R&D results are summarized here.

2. DESIGN OVERVIEW

The two-ring PEP-II facility will be located in the 2200-m circumference PEP tunnel, with the new LER mounted atop the HER. The HER reuses most of the components from the existing PEP ring. A mockup of a proposed arrangement for the two rings is shown in Fig. 1. The injection system for the rings makes use of the present SLC injector, which routinely provides 2.5×10^{10} $e^\pm$ per pulse at 120 pps (compared with a PEP-II design requirement of 0.2–1×10^{10} $e^\pm$ per pulse). With this injector, the estimated top-off time for the operating collider is 3 minutes, and the time to fill the rings from zero current is about 6 minutes. No other injector in the world is as powerful as the SLAC linac, which provides a demonstrated capability to fill the PEP-II rings at a suitable rate. Among other things, such a capability is crucial for an optimum commissioning scenario. A summary of the main PEP-II parameters is given in Table 1.

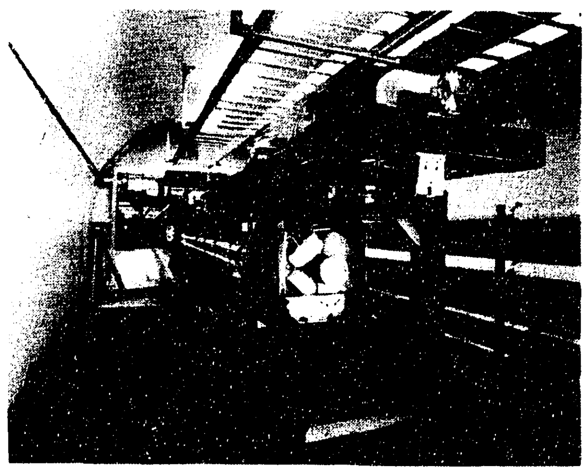

Fig. 1 Mockup of PEP-II magnets and supports.

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Table 1. Main PEP-II Parameters.

	LER	HER
Energy, E [GeV]	3.1	9
Circumference, C [m]	2200	2200
$\varepsilon_y/\varepsilon_x$ [nm·rad]	3.9/97	1.9/48
β_y^*/β_x^* [cm]	1.5/37.5	3.0/75.0
$\xi_{0x,0y}$	0.03	0.03
f_{RF} [MHz]	476	476
V_{RF} [MV]	9.5	18.5
Bunch length, σ_ℓ [mm]	10	10
Number of bunches, k_B	$1658^{\dagger\dagger}$	$1658^{\dagger\dagger}$
Damping time, $\tau_{x,y}$ [ms]	36.4	37.2
Total current, I [A]	2.14	1.48
U_0 [MeV/turn]	1.2	3.6
Luminosity [cm^{-2}s^{-1}]	3×10^{33}	

††includes gap of ≈5% for ion clearing

3. DESIGN OPTIMIZATION

Here we focus on design changes occurring subsequent to the completion of the CDR [1].

3.1 IR Design

The PEP-II interaction region (IR) design is based on an "S-bend" geometry, as illustrated in Fig. 2. Compared with the CDR design, we now have fewer magnets (2 *vs*. 3 IR quadrupoles) and a stronger B1 separation dipole (tapered for maximum strength and minimum interference with the detector solid angle). This configuration leads to additional horizontal separation at the parasitic crossing points (9.6σ *vs*. 7.6σ). Only the Q1 quadrupole is common to both HER and LER. The Q2 magnet is a conventional septum quadrupole acting only on the low-energy beam.

As part of the IR design procedure, we have adopted criteria against which any proposed design is tested. For example, we design for an aspect ratio of $\sigma_y/\sigma_x \geq 0.04$. This minimizes the potential loss in luminosity associated with the beams being tilted at the interaction point (IP), as demonstrated in Fig. 3. Another criterion is to use a "graded aperture" whereby the acceptance at the IR is 15σ, that in the adjacent straight sections is 12.5σ, and that in the arcs is 10σ. This ensures that particle losses will preferentially occur far from the detector. As with all *B* factory projects, we carry out extensive studies of detector backgrounds [2].

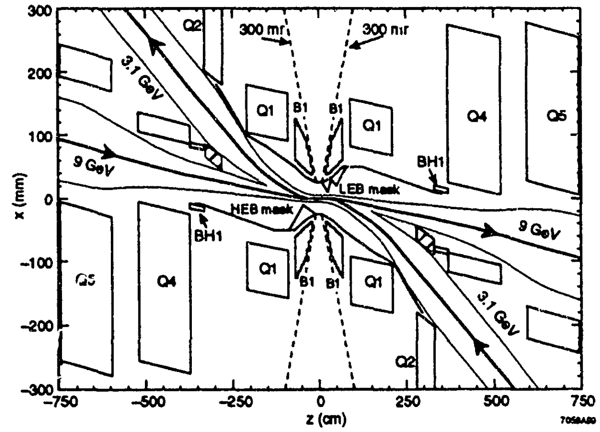

Fig. 2. PEP-II IR layout (anamorphic plan view).

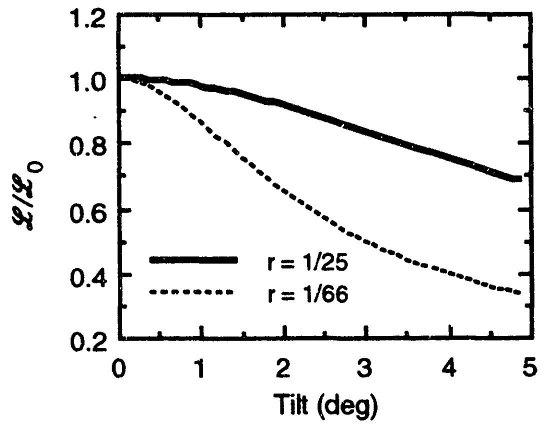

Fig. 3. Sensitivity of luminosity to relative beam tilt.

3.2 Lattice Design

The main changes with respect to the CDR design involve the LER lattice. To increase the emittance contribution and radiation damping from the arcs (thereby reducing the dependence on wigglers), the LER arc dipole length has been reduced from 100 cm to 45 cm. Although the optics implications of this change are nil, it does result in increased thermal and vacuum loads on the chamber. Increasing the width of the LER vacuum chamber to provide additional conductance has made this solution acceptable. The LER arcs now provide half of the required damping decrement and one-third of the required emittance for the LER.

We have also increased the symmetry of the arcs by making the magnet arrangement mirror symmetric about the IP, as described in Ref. [3]. Finally, we are examining [3] the concept of "local" chromaticity correction in which sextupoles are located in the IR straight section itself to control the chromaticity generated by the IR quadrupoles. This approach appears very promising as a means of reducing the higher-order chromaticity that must otherwise be controlled with the arc sextupoles alone.

Based on beam-beam simulations of the injection process [4], we have now adopted a vertical injection scheme for the rings. This keeps the injected beam well away from the stored beam and minimizes the beam blowup during injection. Horizontal injection is still an acceptable option but leads to more blowup and thus potentially more detector background.

3.3 Injection System

Considerable work has been done in this area since the CDR. The optical and mechanical aspects of the e^+ extraction from the linac have been worked out in detail. In addition, a simple and elegant matching technique has been developed that will permit the existing injection transport lines to remain essentially unchanged. A study of injection optics for the storage rings has been made, leading to a simple two-kicker injection scheme. Injection kickers will be powered in parallel to minimize any mismatch between them [5].

To protect the detector from injection losses, three sets of collimators will be installed in each ring. One set serves to define the momentum, one set selects the betatron amplitude, and the third set is for "cleanup." Each of the three sets is designed with multiple sections, separated by 60° or 90° in betatron phase to ensure complete coverage.

4. APPROACH TO R&D ACTIVITIES

Even in the R&D phase, PEP-II activities are being closely monitored. Major R&D activities—those involving significant expense—are formally reviewed as would be done in the construction project. These reviews, which solicit advice from people both inside and outside the immediate PEP-II R&D group, cover R&D goals, technical approach, costs, and schedule. A written report of each review is sent to the reviewers and maintained on file.

5. R&D PROGRESS AND PLANS

R&D activities permit us to verify design choices and optimize design parameters. The key R&D areas for PEP-II were identified early in the design phase and include vacuum, RF, and feedback systems. These are the main topics on which PEP-II R&D is focusing.

It is worth noting that the results of the R&D activities are continually folded back into the project design. Examples of this include the down-sampling feature added to the multibunch feedback system [6], the detailed calculations of the higher-order mode (HOM) damping and thermal loading of the RF cavities [7], and the simplified approach to the HER vacuum chamber design [8]. Such modifications produced the beneficial side-effect of reducing overall project costs so, in a certain sense, the R&D effort is "paying for itself."

5.1 Vacuum System

We have carried out extensive photodesorption studies using the VUV ring at BNL [9]. Initial studies used copper bars to choose acceptable materials for the chamber, and subsequently an actual chamber was studied to examine fabrication and cleaning issues. The entire topic of chamber production is being studied in detail to determine optimum fabrication, cleaning, and assembly techniques. We are also preparing a series of tests on the pumping speed of distributed ion pumps (DIPs) to optimize the pumping cell design and verify the pumping speed of our chosen configuration.

The status of this work [8] is that materials choices have been made (OFHC copper for the chamber body and SE-copper for the cooling bar), and the required photodesorption coefficient, $\eta \leq 2 \times 10^{-6}$, has been achieved after an equivalent PEP-II photon dose of only 25 A·hr. A DIP test facility is designed and is being fabricated, with pumping tests scheduled to begin soon. We are also exploring alternative techniques to weld and bend extruded HER chambers, with promising results.

5.2 RF System

The R&D goals of the RF system program have included fabricating a low-power test cavity and measuring its HOM properties. In addition, tests to verify the efficacy of the proposed waveguide damping scheme have been carried out, resulting in damping of the most dangerous longitudinal HOM (TM011) to $Q \approx 30$ (compared with a desired reduction to $Q < 70$). A program of three-dimensional thermal and mechanical stress calculations for the RF cavity is being carried out in collaboration with the AECL Chalk River Laboratory (CRL) to devise a suitable cooling scheme for the high-power cavity [10]. A high-power test stand that can be used for the cavity tests (150 kW design goal) and window tests (500 kW design goal) is now available, powered by a 500-kW modified PEP klystron retuned to 476 MHz. Considerable emphasis has been placed on the development of an RF feedback system to avoid driving coupled-bunch instabilities with the fundamental mode [11].

The state of the RF work is well advanced. The low-power cavity is completed and measurements of the HOM spectrum have been carried out [7]. We have demonstrated that the waveguides and loads effectively damp the unwanted HOMs. A detailed simulation model of the RF feedback system has been carried out in collaboration with CRL and the results are very promising.

5.3 Feedback System

The feedback system R&D in the past year has concentrated on optimizing the design of the longitudinal system. In addition to carrying out simulations with realistic parameters, we have carried out actual system tests with beam, using the SPEAR ring at SLAC [12]. We are also refining the design of the transverse feedback systems.

Our simulations have shown that the down-sampled design is both simple and effective, and that realistic noise and bunch-to-bunch coupling in pickup and kicker do not degrade system performance. The SPEAR measurements verify that the system performs properly and understandably under "combat" conditions. At the present time a full prototype system is being designed. This will be installed and tested at the LBL Advanced Light Source (ALS) in about one year.

5.4 Magnets and Supports

In the past year we have completed a full-cell hardware mockup of the PEP-II rings (see Fig. 1) and performed mechanical stability and alignment tests. Magnet refurbishment procedures have also been developed and tested, and were shown to be less complicated and less expensive than originally assumed in the CDR. Based on this work, we intend to modify the LER support structure for better alignment line-of-sight.

5.5 Ongoing R&D Program

In the current year, R&D efforts will focus on answering the remaining questions on major issues required for construction. For the vacuum system, we plan to obtain prototype HER extrusions and use them to carry out a realistic fabrication sequence. We will also perform photodesorption measurements on sample extruded chambers using the higher critical energy photons of the XRAY ring at BNL. DIP tests will be completed and an optimized design determined. The modified PEP-II full-cell mockup will be used as a test bed for installing a full-cell vacuum system mockup with all components and chamber supports. Impedance measurements of the various chamber components will also be performed.

The main RF-related R&D activity will be associated with the final design, fabrication, and testing of a high-power test cavity. This work will include tests of high-power cavity windows and damping loads using the SLAC 500-kW, 476-MHz test stand. Development work on a 1.2-MW, 476-MHz klystron will continue.

Feedback work will concentrate on the production of a prototype PEP-II system suitable for testing on the ALS. This requires both software and hardware development.

Injection-related work will include verifying the design of the linac extraction system and confirming the parameters (emittance, energy spread) of the extracted beam. Design and testing of the required injector feedback algorithms will also be carried out.

In the area of magnets and supports, we plan to modify the full cell mockup to conform to the final configuration adopted. As mentioned, the vacuum system and its supports will be included in this setup. A prototype LER quadrupole will be fabricated and measured to ensure it meets field-quality requirements.

The LER lattice design will be finalized, based on a local chromaticity correction scheme. Tracking calculations to verify dynamic aperture and to determine alignment and field tolerances will be completed. We also plan to begin a study of a low momentum compaction lattice concept to see what benefits this approach might offer.

The IR design R&D program will be aimed at optimizing the vacuum close to the IP. Background studies will be updated to reflect any LER lattice changes that occur.

6. SUMMARY

Major progress has been made on the PEP-II design in the past year. Technical uncertainties have been successfully eliminated and no significant new problems have been uncovered. R&D activities are also well under way and have resulted in important design improvements. The issues being studied by the PEP-II team are of great interest to the entire new generation of colliders and storage rings, including *B*, Φ, τ-charm factories, hadron colliders (SSC, LHC) and new generation light sources.

The PEP-II project has a strong design team combined with an excellent site from which to mount it. We are looking forward to receiving soon the go-ahead to begin construction.

7. ACKNOWLEDGMENTS

I would like to thank A. Chan for help with the preparation of the figures.

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